A Simulation Study Of Economic Production Quantity Lot Size To Kanban For A Single Line Production System Under Various Setup Times With Average Work In Process (WIP) Inventory Cost As Performance Metric

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ABSTRACT

The Setup time variable was evaluated for the two systems (Kanban and EPQ) against the performance measure of average WIP inventory cost. EPQ outperforms Kanban on average WIP inventory cost at setup times less than 8 minutes. The research helped clarify for practitioners whether EPQ might be more suitable than Kanban for their given situations.

Keywords: Production Systems; Kanban; Economic Production Quantity; Economic Order Quantity; EPQ; EOQ; Setup; Simulation

INTRODUCTION

There are advantages to both Economic Production Quantity (EPQ) model and the Kanban model (Nicholas, 1998). The EPQ is a variation of the economic order quantity model (EOQ) but, unlike in the EOQ model where orders are received all at once, orders in the EPQ model are received gradually over time.

The objective of this study is to fill a research gap by evaluating EPQ to Kanban for a single line, multi-product item production system under various setup times. The objective will be accomplished by utilizing simulation to evaluate Kanban and EPQ production systems. The primary variable is setup time. The performance measure is average WIP inventory cost. This research will help practitioners determine the conditions under which the EPQ and the Kanban systems are more appropriate for them so that their companies could better compete in the competitive global marketplace.

The Arena[1](Kelton et al., 2002) simulation package will be used to carry out simulation of the Kanban and EPQ production systems and the results will be analyzed using statistical methods from Arena. The performance metric used is average WIP inventory cost, measured by the average inventory cost of products in the whole production line per day. This includes the products being processed at the machines and the products stored in buffers. Units of measure are dollars.

[1] Arena is a registered Trade Mark of Rockwell Software, In., Sewickley, PA.

LITERATURE REVIEW

There has been very little research evaluating EPQ and Kanban in one study. Choi (1998) does some indirect comparisons while others (Louis, 1997; Mason, 1999; Morquecho, 1997; Newman, 1992) have done MRP and Kanban/JIT comparisons that incorporate some aspects of EOQ versus Kanban. Jaber and Bonney (1999) and Jones (1991) have discussed some type of integration of EOQ and Kanban. Schonberger (1982), Monden (1983), and Hopp and Spearman (1996) have discussed the different systems separately, but did not compare one to the other.

RESEARCH VARIABLE

Setup time is the variable that is used to evaluate the EPQ and Kanban control systems. Setup time is the time to change a machine over to be ready to manufacture a product type.

METHODOLOGY

The simulation language to be used in this study is Arena (Kelton et al., 2002), a SIMAN based simulation package. For a complete treatment of SIMAN the interested reader is referred to Pegden et al. (1995). The Kanban and EPQ production systems and the results will be analyzed using statistical methods from Arena. Average WIP inventory cost is the performance metric.

Research Question And Hypothesis

In a station-to-station shop with setups, does a Kanban controlled or an EPQ controlled process have lower average WIP inventory cost?

Table 1: Research Design And Combinations

System	Variable	Performance Metric
1. EPQ	1. Setup Time: 1, 5, 10, 15, 30, 60 Minutes	1. Average WIP inventory cost
2. Kanban	2. Setup Time: 1, 5, 10, 15, 30, 60 Minutes	2. Average WIP inventory cost

General Description Of Simulation Models

The Kanban and EPQ simulations emulate the manufacture of a finished product that needs no assembly. This study is a simulation of a serial flow shop with kanban container size of 5, 10, and 15. The intent of using different container sizes is to enhance any differences between Kanban and EPQ, and to investigate changes as the size of the container increase.

A five-workstation simulation was chosen to reduce the complexity that occurs in a larger simulation. This requirement (five stations) is needed to fully test the methods of control. A review of the past literature demonstrated that a five-station flow line is adequate in representing the various real and hypothetical flow lines cited in literature (Yang, 2000).

Kanban Control Simulation Model

The simulation model is a two-card Kanban system. There are two buffers between each pair of workstations. This study utilized a five-station Kanban system. A graphical representation of the Kanban simulation model is shown in Figure 1 (Gupta and Al-Turki, 1998).

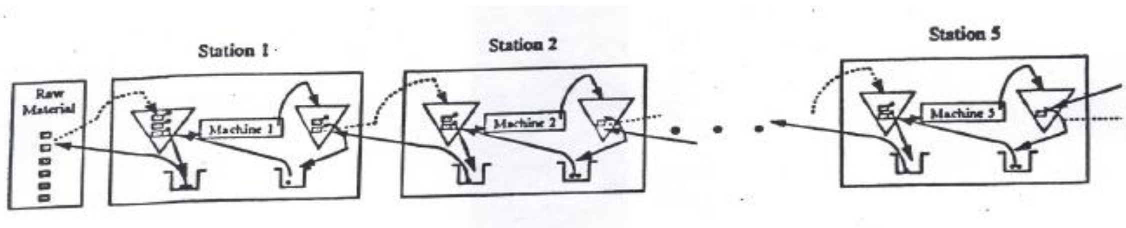

Figure 1: Kanban Simulation Model (Gupta and Al-Turki, 1998).

EPQ Control Simulation Model

Figure 2 is a graphical representation of the WIP inventory arrangement between each pair of workstations of the EPQ simulation model. The process batch size specifies the number of units to be completed between setups. When the process batch is complete the workstation undergoes a setup for the next product in line.

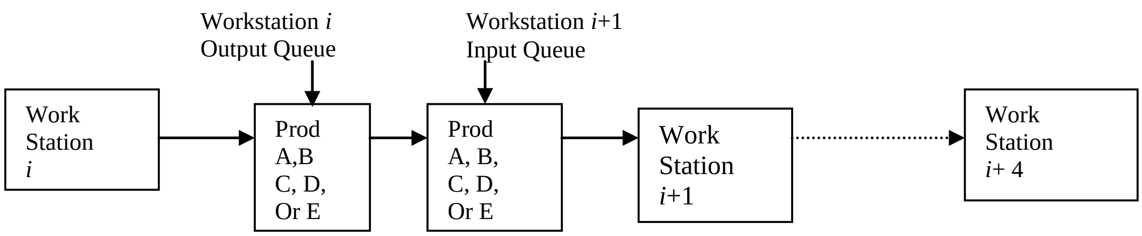

Figure 2: EPQ Simulation Model

Statistical Technique

Since this is an exploratory multi-factor study, analysis of variance (ANOVA) is considered appropriate. The intent of the study is not to determine the exact nature of the relationship between the independent and dependent variables, but to determine if a relationship exists. This information will be provided by ANOVA (Kelton, 2002).

The hypotheses are concerned with contrasting the effects of setup time on Kanban and EPQ individually.

Average WIP inventory cost is the primary focus of the study.

The level of significance for statistical tests of primary factor and interaction effect is 0.05. The alternatives for the statistical test for the primary and interaction effects are:

Ho: factor effect = 0, the factor has no effect
Ha: factor effect ≠ 0, the factor does have an effect

The decision rule is:

If P value ≥ 0.05, conclude Ho
If P value < 0.05, conclude Ha

Table 2: Simulation Model Parameters

I. Factory environment/fixed assumptions applicable to both EPQ and Kanban	
Parameter	Values
Demand	2000 units a year for each product 1 year = 50 weeks; 1 week = 5 days; 1 day = 24 hours
Setup Costs	$60.00 per hour
Annual Holding Cost Rate	20%
Production Cost	$80.00 per unit Each of the 5 workstations adds $16.00 of costs
Processing Time	20 minutes per part total 4 minutes per workstation, gamma distribution $\alpha = 2$, $\sigma^2 = 8$
Number of Work Stations	5
Number of Products	5
II. EPQ assumptions and variables	
Parameter	Values
Setup Time (Primary variable)	1, 5, 10, 15, 30, 60 minutes. With a gamma distribution, $\alpha = 2$.
Process Batch Size	EPQ: 84, 188, 266, 325, 460, 651 (based on EPQ formula, refer to Nicholas, 1998). Batch sizes correspond to setup times of 1, 5, 10, 30, and 60 minutes respectively.
EPQ (Transfer Batch)	1 unit
III. Kanban assumptions and variables	
Parameter	Values
Setup Time (Primary variable)	1, 5, 10, 15, 30, 60 minutes. With a gamma distribution, $\alpha = 2$.
Kanban Container Size	5, 10, 15 units
Process Batch Size	Number of production kanban: 1 kanban per work station Number of withdrawal kanban: 1 kanban per work station (based on kanban formula, refer to Nicholas, 1998).
Kanban (transfer batch), which is kanban container size	5, 10, and 15 units per kanban container

Number of Replications

The number of replications to obtain the desired precision is automatically calculated by the Arena software. The desired precision is a 95% confidence that the estimated means are within 0.1% of the true mean on the Total Cost measure. Both the EPQ and Kanban simulations were utilized for this determination.

Verification of EPQ and Kanban Simulation Model

Verification entails ensuring that the logic of the model is good. To accomplish this, the logic constructs selected for the modules that were used were compared to the system parameters delineated in Table 2. It was determined that the model met these parameters.

In addition, further verification was accomplished by running the simulation with animation. As stated, “Animation is often very useful during the verification and validation phases because it presents the entire system being modeled as it operates” (Kelton et al., 2002). It was determined that with the animation that the model appeared to operate very similar to the way the system was described.

The Kanban simulation was run for a setup time of 5 minutes and kanban container size of 10. It was run for 51 replications. The results were analyzed and the values had face validity. It was therefore concluded validated.

Research Caution on Comparing EPQ to Kanban System

This study is making an evaluation of the Kanban and EPQ control systems. The EPQ and Kanban systems are two different systems and direct comparisons can be difficult to make. Since these are two different systems, direct statistical analysis between the systems cannot be made. However, general overview statements can be made when making a comparison between the two systems.

A statistical analysis of effect of setup time on Kanban system and EPQ system will be made in this research. These are made separately. A general overview statement can and will be made comparing the two systems in the conclusion.

RESULTS

Once the simulation model was tested and verified, data was collected to analyze the Kanban and EPQ systems. The model provided the data on the performance measure of average WIP inventory cost. Units of measure are dollars.

Results of EPQ/Kanban, WIP Cost vs. Setup Time

Does setup time affect the average WIP inventory cost of the Kanban controlled process vs. EPQ system? The mean values of the average WIP inventory cost are plotted for each of the Kanban systems (5, 10, and 15) and EPQ system in Figure 3. As Figure 3 shows, EPQ WIP Costs are less than the Kanban 10 and Kanban 15 at setup time of 1 minute. But as the setup time increases beyond approximately 12 minutes, the EPQ WIP costs become greater than each of the Kanban Systems (5, 10, and 15). Also, as the setup time increases beyond approximately 12 minutes the difference of the average WIP inventory cost increases between EPQ and each of the Kanban systems (5, 10, and 15). It can be generally stated that increasing the setup time increases the difference in WIP costs between the Kanban controlled and EPQ controlled processes. Figure 3 supports this conclusion.

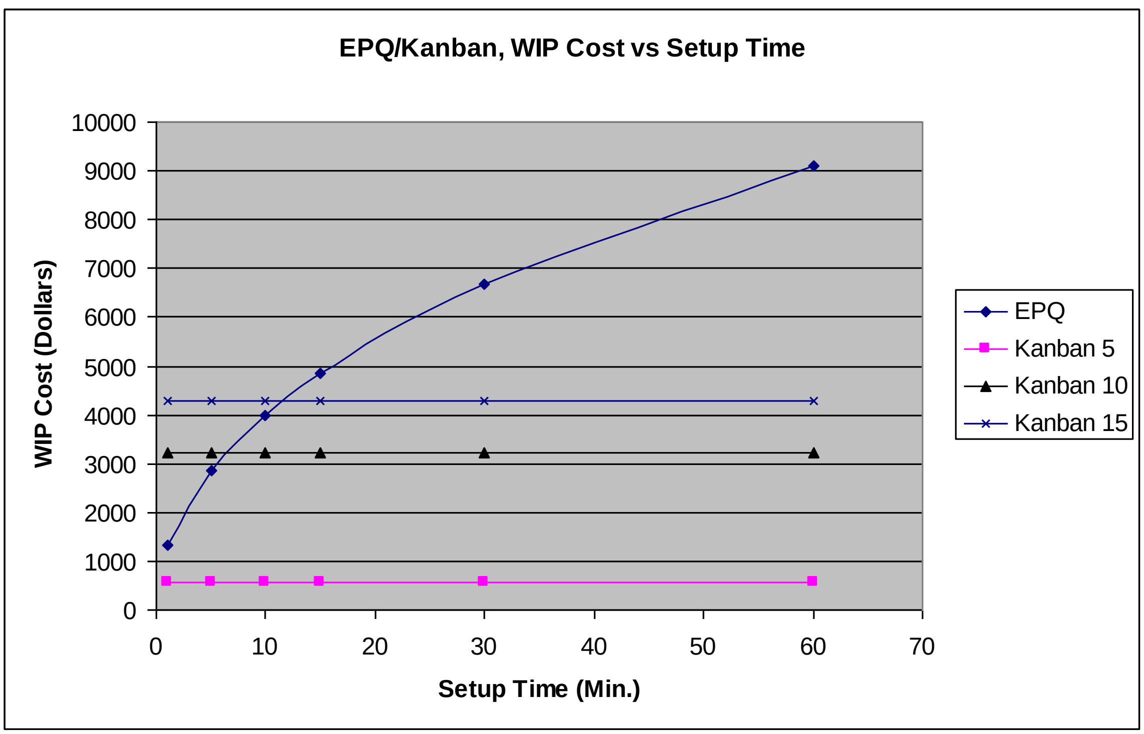

Figure 3: EPQ/Kanban, WIP Cost vs. Setup Time

This higher average WIP costs for the EPQ system vs. Kanban (at approximately 12 minutes and greater) can be explained that as setup times increase the EPQ lot sizes get larger (thereby higher WIP costs) than Kanban system. Recall that with EPQ lot sizes are a function of setup times. When setup time is less than approximately 12 minutes, the EPQ WIP costs fall below Kanban 15. When setup time is less than approximately 8 minutes, the EPQ WIP costs fall below both Kanban 15 and Kanban 10.

SUMMARY

This research is exploratory with the objective of testing theory and making evaluations of Kanban and EPQ control methods. The research studied the effects of the variable setup time on average WIP inventory cost. The model simulated a multi-product, station-to-station shop with setups. The research question addressed was, "In a station-to-station shop with setups, does a Kanban controlled or an EPQ controlled process have lower average WIP inventory cost?"

Effect of Setup Time between Kanban and EPQ

The **s**etup time variable was evaluated for the two systems (Kanban and EPQ) against the performance measures of average WIP inventory cost. Even though a direct statistical comparison cannot be made between Kanban and EPQ some general conclusions can be made. The results of these analyses are summarized in Table 3.

Table 3: Kanban vs. EPQ summary of the results

Variable Setup Time				
Performance Measure	**EPQ**	**Kanban 5**	**Kanban 10**	**Kanban 15**
Average WIP inventory cost	EPQ superior to Kanban 15 at setup times less than 12 minutes. EPQ superior to Kanban 10 at setup times less than 8 min.	Kanban 5 superior to all at all setup time	Kanban 10 superior to Kanban 15 at all setup times	Kanban 15superior to EPQ at setup times greater than 12 minutes

CONCLUSIONS AND MANAGERIAL IMPLICATIONS

By evaluating the Kanban and EPQ in a single study, this research offers managers a better understanding of choosing the correct production system for their multi-product production line. This contribution is significant because it evaluates the different systems and provides insights on selecting the correct system for a multi-product production system.

The expected finding for the research question was that when setup times are high (greater than 30 minutes), Kanban will have lower average WIP inventory costs. It was expected that EPQ will have lower average WIP inventory cost at some setup time of less than 15 minutes.

On the measure of average WIP inventory cost while varying setup time, Kanban outperforms EPQ at setup times greater than 12 minutes. EPQ outperforms Kanban 15 at setup times of less than 12 minutes and outperforms Kanban 10 at setup times less than 8 minutes. These findings proved the expected results. More importantly the research gives practitioner a tool to evaluate their situation. It demonstrates the importance of kanban container size and setup time on the WIP inventory cost, which was the performance metric.

An advantage of the Kanban system is that it has some more flexibility than EPQ. It is a method of adapting to changes due to problems and demands by having all processes produce the necessary product at the necessary time. An advantage of the EPQ is that it has lower overall annual setup cost. This is partially accomplished by producing in larger lots and therefore reduces the number of setups required and the resultant setup costs.

SPECIFIC LIMITATIONS AND SUGGESTIONS FOR FUTURE STUDY

The major focus of this research was the impact of setup time on EPQ and Kanban systems. Therefore some of the factors known to affect performance but that are outside the realm of the research had to be controlled. Three areas that were held constant in this research and would be of interest of further study would be demand, number of workstations, and number of products.

Demand: It is not the intention of this research to study the impact of demand variation on performance. We assumed that the demand was constant at 2000 parts a year for each of the products. An area of future research would be to vary demand.

Number of workstations: The simulation utilized a five-workstation system chosen to reduce the complexity that occurs in a larger simulation. An area of future research would have a simulation of larger than 5 workstations.

Number of products: The product mix was held constant at 5 products. This is not realistic in the real world where product mixes change. An area of future study would have a variety of product mixes.

AUTHOR INFORMATION

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NOTES

